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(54) **Method of diagnosing leakage in an internal combustion engine common-rail injection system**

(57) There is described a method of diagnosing leakage in a common-rail injection system (1) of an internal combustion engine (2) having a number of cylinders (4); the injection system (1) having a number of injectors (14), each supplying high-pressure fuel to a respective cylinder (4) of the engine (2), and a fuel supply circuit (16, 18) supplying fuel to the injectors (14). The diagnosis method includes the steps of determining the contribution (AC_i) of each cylinder (4) to the angular acceleration of the engine (2); determining, for each cylinder (4), an unbalance index (IS_i) indicating the unbalance of the angular acceleration contribution (AC_i) of the cylinder (4) with respect to the angular acceleration contributions (AC_i) of the other cylinders (4); reducing, upon detection of a fault in the injection system (1), the amount of fuel injected into each cylinder (4); and distinguishing, for each injector (14), between a jammed-open injector condition and a fault condition in the fuel supply circuit (16, 18), on the basis of the variation in the unbalance index (IS_i) of the respective cylinder (4) following the fuel reduction.

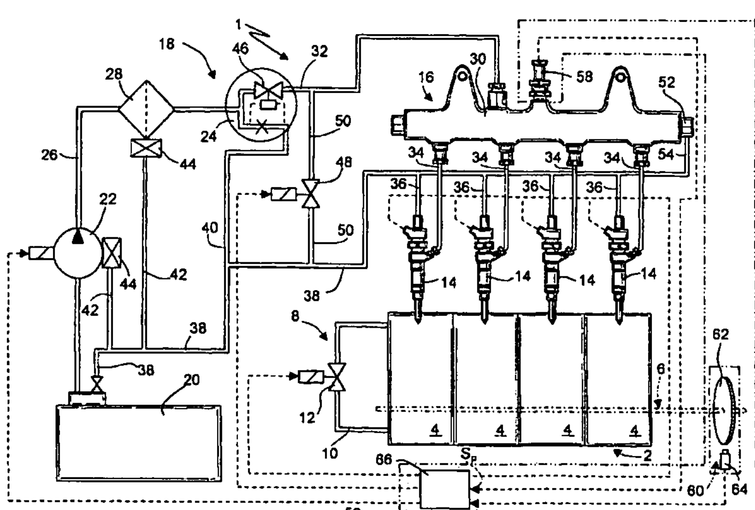

Fig.1

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Description

[0001] The present invention relates to a method of diagnosing leakage in an internal combustion engine common-rail injection system.

[0002] As is known, of the various problems that can occur in a common-rail injection system, the worst and most dangerous are one or more of the injectors jamming in the open position, and fuel leakage in the high-pressure fuel supply circuit, which results in fuel discharge in the form of a very fine spray.

[0003] On the one hand, high-pressure fuel leakage may cause a fire if the fuel spray should strike particularly hot engine surfaces; and, on the other, a jammed-open injector results in continuous fuel supply to the cylinders, in turn resulting not only in excessive fuel consumption but also in abnormal combustion characterized by pressure peaks and a considerable temperature increase in the cylinders.

[0004] Such defects can only be tolerated so long without causing serious damage to the engine, e.g. to the connecting rod, piston, or injector nozzles, and may immediately impair performance and safety of the vehicle.

[0005] To safeguard against such hazards, diagnostic units were proposed to detect fuel leakage in the injection system and to act on the injection system to cut off fuel supply to the injectors and so stop the engine immediately.

[0006] More specifically, such units operated by comparing the fuel pressure in the common rail or total fuel consumption of the engine with respective threshold values, and determined the presence or not of any hazardous situations accordingly.

[0007] Common-rail injection systems, however, are also subject to fuel leakage in the low-pressure fuel supply circuit - caused, for example, by fine cracks in the low-pressure conduits - or to faulty low-pressure fuel supply circuit components preventing correct fuel supply to the high-pressure fuel supply circuit.

[0008] Such leakage and defects, however, are not as serious as a jammed-open injector or high-pressure fuel spray, by not immediately impairing engine performance or the safety of the vehicle, which, in such cases, in fact, can safely be driven at least to the nearest repair shop.

[0009] Known diagnostic units of the above type, however, were unable to distinguish between fuel leakage in the high-pressure fuel supply circuit and fuel leakage or faults in the low-pressure fuel supply circuit, so that, even in the case of minor, nonhazardous faults in the low-pressure fuel supply circuit, known diagnostic units immediately disabled the vehicle, thus causing considerable inconvenience to the driver, out of all proportion to the immediate danger involved.

[0010] One of the many solutions proposed to at least partly eliminate the above drawback is described in the Applicant's European Patent Application EP-0786593, which proposes a fuel catch structure for determining fuel leakage from the high-pressure fuel supply conduits connecting the injectors to the common rail.

[0011] More specifically, the fuel catch structure comprises a number of sleeves made of elastomeric material, surrounding the injector supply conduits, and for catching any fuel leaking from the conduits; a catch header connected to and for collecting from the sleeves any fuel leaking from the injector supply conduits; a fluid sensor located at the bottom of the catch header to generate a leak signal indicating the presence of fuel in the catch header; and an alarm circuit connected to the fluid sensor to generate an alarm signal in the presence of fuel in the catch header.

[0012] Though advantageous in many respects, the above solution has several drawbacks preventing its advantages from being fully exploited.

[0013] More specifically, fuel leakage from the high-pressure supply conduits is determined using additional dedicated components not normally provided on the vehicle - such as the sleeves, catch header, fluid sensor, and alarm circuit - and which, besides costing money to manufacture or purchase and assemble, also call for regular servicing.

[0014] Moreover, the catch structure described above was only capable of determining one type of fault in the high-pressure fuel supply circuit - namely, fuel leakage from the high-pressure supply conduits - so that any other faults in the high-pressure fuel supply circuit, such as a jammed-open injector, remained undiagnosed.

[0015] Another solution proposed to at least partly eliminate the above drawbacks is described in the Applicant's European Patent Application EP-0785349, which proposes a diagnostic unit designed to determine the type of fault in the high-pressure fuel supply circuit, and in particular to distinguish between a jammed-open injector and a generic fault in the high-pressure fuel supply circuit.

[0016] More specifically, the diagnostic unit employs an accelerometer signal related to engine vibration intensity and generated by an accelerometer sensor on the engine block; and a position signal indicating the angular position of the drive shaft (engine angle). More specifically, the diagnostic unit compares the amplitude of the accelerometer signal with a first reference value; compares with a second reference value the engine angle value at which the amplitude of the accelerometer signal exceeds the first reference value; and determines a jammed-open injector condition according to the outcome of the two comparisons.

[0017] Though advantageous in many respects, the above solution has one drawback preventing its advantages from being fully exploited.

[0018] More specifically, the type of fault in the high-pressure fuel supply circuit is determined using an additional dedicated component not normally provided on the vehicle, i.e. the accelerometer sensor, which, besides costing money to manufacture or purchase and assemble, also calls for regular servicing.

[0019] To eliminate the above drawback, the Applicant's European Patent Application EP-0785358 proposes a diagnostic unit designed to determine the type of fault in the fuel supply circuit as a whole, and in particular to distinguish between a jammed-open injector and a generic fault in the fuel supply circuit, without requiring the use of an additional accelerometer sensor not normally provided on the vehicle.

[0020] More specifically, the diagnostic unit first determines the presence of faults in the fuel supply circuit by comparing the fuel pressure in the common rail or the total fuel consumption of the engine with respective threshold values; and, in the event any faults are determined, distinguishes between a jammed-open injector and a generic fault in the fuel supply circuit on the basis of the engine torque, which is determined using a position and speed signal indicating the speed and angular position of the drive shaft and generated by a drive shaft speed and angular position detecting device already provided on the vehicle and substantially comprising a sound wheel fitted to the drive shaft, and an electromagnetic sensor associated with the sound wheel.

[0021] More specifically, if any faults are detected in the fuel supply circuit, the diagnostic unit reduces - in particular, cuts off - fuel injection into each engine cylinder; calculates, on the basis of said position and speed signal, the contribution of each cylinder to the value of the useful torque generated by the engine; compares each contribution with a respective reference value; and determines a jammed-open injector condition when at least one contribution is above the respective reference value, and a fault condition in the fuel supply circuit when all the contributions are below the respective reference values.

[0022] That is, if the diagnosed fuel leakage is caused by a fault in the fuel supply circuit, the reduction in the amount of fuel injected into the cylinders produces a corresponding reduction in the useful torque contribution of each cylinder; which reduction can easily be calculated as a function of the reduced injection time of each injector. Conversely, if the diagnosed fuel leakage is caused by a jammed-open injector, the reduction in the amount of fuel injected produces a smaller reduction in useful torque contributions than in the previous case, owing to the jammed-open injector feeding fuel continuously to the respective cylinder, which therefore shows no reduction in its contribution to the useful torque generated by the engine.

[0023] Though advantageous in many respects, the above solution has a minor drawback preventing its advantages from being fully exploited.

[0024] More specifically, a jammed-open injector is distinguished from a generic fault in the high-pressure supply circuit by comparing with a respective reference value the contribution of each cylinder to the useful torque generated by the engine. Computer simulation and road tests conducted by the Applicant, however, show fault diagnoses based on the above comparison to be unreliable in certain engine operating conditions. In particular, fault recognition problems may arise during transient operating states of the engine, e.g. during release.

[0025] It is therefore an object of the present invention to provide a leakage diagnosis method designed to eliminate the aforementioned drawbacks.

[0026] According to the present invention, there is provided a method of diagnosing leakage in a high-pressure injection system of an internal combustion engine, as defined in Claim 1.

[0027] A preferred, non-limiting embodiment of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a simplified diagram of a common-rail injection system;

Figure 2 shows a flow chart of the leakage diagnosis method according to the present invention.

[0028] Number 1 in Figure 1 indicates as a whole a common-rail injection system for an internal combustion engine, in particular a diesel engine, 2 comprising a number of cylinders 4, an output shaft 6 (shown schematically by the dot-and-dash line), and an exhaust gas recirculation (EGR) system 8.

[0029] More specifically, exhaust gas recirculation system 8 provides for feeding part of the exhaust gas in the exhaust manifold of the engine back into the intake manifold of engine 2, for reducing the combustion temperature and the formation of nitric oxide (NOx), and is shown schematically in Figure 1 by a conduit 10 fitted with a regulating valve 12.

[0030] Injection system 1 substantially comprises a number of injectors 14 supplying high-pressure fuel to cylinders 4 of engine 2; a high-pressure supply circuit 16 supplying high-pressure fuel to injectors 14; and a low-pressure supply circuit 18 supplying low-pressure fuel to high-pressure supply circuit 16.

[0031] Low-pressure supply circuit 18 comprises a fuel tank 20; a supply pump 22, e.g. electric, immersed in the fuel in tank 20 (but shown outside tank 20 for reasons of clarity); a high-pressure pump 24 connected to supply pump 22 by a low-pressure supply line 26; and a fuel filter 28 located along low-pressure supply line 26, between supply pump 22 and high-pressure pump 24.

[0032] High-pressure supply circuit 16 comprises a known common rail 30 connected by a high-pressure supply line 32 to high-pressure pump 24, and by respective high-pressure supply conduits 34 to injectors 14, which are also connected by respective recirculating conduits 36 to a drain line 38, in turn connected to tank 20 to feed back into tank 20 part of the fuel used in known manner by and for operation of injectors 14.

[0033] Drain line 38 is also connected to high-pressure pump 24 by a respective recirculating conduit 40, and to supply pump 22 and fuel filter 28 by respective recirculating conduits 42 and respective overpressure

valves 44.

[0034] High-pressure pump 24 is fitted with an on/off, so-called shut-off, valve 46 (shown schematically) for permitting supply to the pumping elements (not shown) of high-pressure pump 24 when a difference in pressure exists between low-pressure supply line 26 and recirculating conduit 40.

[0035] High-pressure supply circuit 16 also comprises a pressure regulator 48 connected between high-pressure supply line 32 and drain line 38 by a recirculating conduit 50, and which, when activated, provides for feeding back into tank 20 part of the fuel supplied by high-pressure pump 24 to common rail 30, and so regulating, in known manner not described in detail, the pressure of the fuel supplied by high-pressure pump 24, and hence the fuel pressure in common rail 30.

[0036] High-pressure supply circuit 16 also comprises a pressure relief device 52 connected on one side to common rail 30 and on the other side by a recirculating conduit 54 to drain line 38, and which prevents the fuel pressure in common rail 30 from exceeding a predetermined maximum value.

[0037] Injection system 1 also comprises a diagnostic unit 56 for detecting and diagnosing leakage in injection system 1.

[0038] More specifically, diagnostic unit 56 comprises a pressure sensor 58 connected to common rail 30 and generating a pressure signal S_P related to the fuel pressure in common rail 30 and therefore to the fuel injection pressure; and a detecting device 60 for detecting the speed and angular position of output shaft 6, and in turn comprising a known sound wheel 62 fitted to output shaft 6, and an electromagnetic sensor 64 facing sound wheel 62 and generating a position and speed signal S_A indicating the speed and angular position of sound wheel 62 and therefore the speed and angular position of output shaft 6.

[0039] Diagnostic unit 56 also comprises an electronic central control unit 66 (forming part, for example, of a central engine control unit not shown) for controlling injection system 1, and which receives pressure signal S_P and position and speed signal S_A, generates a first control signal supplied to pressure regulator 48, a second control signal supplied to supply pump 22, and a third control signal supplied to injectors 14, and performs the operations described below with reference to Figure 2 to:

- determine the presence of a fault in injection system 1;
- determine whether the fault is due to one or more jammed-open injectors; or to leakage in the fuel supply circuit caused, for example, by cracks in the highpressure conduits; or to a generic fault in the low-pressure supply circuit; and
- act appropriately on injection system 1 according to the type of fault diagnosed.

[0040] More specifically, each of the leakage diagnosis operations described below with reference to the Figure 2 flow chart is repeated by electronic central control unit 66 at a frequency which, as opposed to being constant, depends on the speed of engine 2.

[0041] For example, each of the leakage diagnosis operations in the Figure 2 flow chart may be performed by electronic central control unit 66 at each fuel injection, i.e. at each engine cycle.

[0042] More specifically, as shown in Figure 2, electronic central control unit 66 first acquires pressure signal S_P and position and speed signal S_A (block 100), and determines, as a function of pressure signal S_P, the instantaneous pressure value P_{RAIL} of the fuel in common rail 30, and, as a function of position and speed signal S_A, a quantity AC_1 related to the contribution of each cylinder 4 to the useful torque generated by engine 2 (block 110).

[0043] More specifically, quantity AC_1 is defined by the contribution of each cylinder 4 to the angular acceleration of output shaft 6 of engine 2, which is hereinafter referred to as "angular acceleration contribution AC_i" - where the subscript "i" indicates the respective cylinder 4 - and may, for example, be calculated as described in detail in the Applicant's European Patent Application EP 637738.

[0044] Calculating the angular acceleration contribution, as opposed to the torque contribution, of each cylinder 4 is preferred, firstly, because, as is known, the two quantities are closely related - in particular, are proportional - and, secondly, because calculating the torque contribution of each cylinder necessarily involves calculating the angular acceleration contribution anyway.

[0045] Electronic central control unit 66 then filters the angular acceleration contributions AC_i of each cylinder 4 to generate, for each cylinder 4, a sequence of filtered angular acceleration contributions ACF_1 (block 120). More specifically, angular acceleration contributions AC_i of each cylinder 4 are filtered in known manner, not described in detail, using a conventional low-pass numeric filter with a pass band for attenuating oscillations in engine speed induced by transmitting torque from the engine to the wheels.

[0046] As a function of respective filtered angular acceleration contributions ACF_1, electronic central control unit 66 then calculates (block 130), for each cylinder 4, an unbalance index IS_i indicating the unbalance of the respective filtered angular acceleration contribution ACF_i with respect to the mean values of the filtered angular acceleration contributions ACF_i of the other cylinders 4, and which is calculated according to the equation:

$$IS_i = ACF_i - \sum_{j \neq i} \left(a_j \cdot ACF_j\right)$$

where a_j is the weight attributed to each filtered angular acceleration contribution ACF_i, and may, for example, be a constant value $a_j=1/(n-1)$, where n equals the number of cylinders 4 of engine 2.

[0047] Electronic central control unit 66 then filters the unbalance indexes IS_i of each cylinder 4 to generate, for each cylinder 4, a sequence of filtered unbalance indexes ISF_i (block 140). More specifically, the unbalance indexes IS_i of each cylinder 4 are filtered in known manner, not described in detail, using a conventional numeric filter.

[0048] Simultaneously with the above operations in blocks 100-140, electronic central control unit 66 compares the instantaneous pressure value P_{RAIL} of the fuel in common rail 30 with a minimum pressure value P_{MIN}, which is a function of engine speed and represents the minimum fuel pressure below which injection system 1 is definitely malfunctioning and calls for a procedure to determine the cause (block 150).

[0049] For example, minimum pressure value P_{MIN} may range between 120 and 200 bars, and, in particular, may be about 120 bars for engine speeds below 2300 rpm, about 200 bars for engine speeds over 2500 rpm, and may increase linearly from 120 to 200 bars for engine speeds between 2300 and 2500 rpm.

[0050] If instantaneous pressure value P_{RAIL} is greater than or equal to minimum pressure value P_{MIN} (NO output of block 150), electronic central control unit 66 diagnoses no fault in injection system 1 and goes back to the input of block 150 to continue comparing instantaneous pressure value P_{RAIL} and minimum pressure value P_{MIN}. Conversely, if instantaneous pressure value P_{RAIL} is below minimum pressure value P_{MIN} (YES output of block 150), electronic central control unit 66 diagnoses a leak in injection system 1 and performs the operations described below to determine whether leakage is due to one or more jammed-open injectors, or to a generic fault in high- and low-pressure supply circuits 16, 18.

[0051] More specifically, upon the fuel leakage being detected, electronic central control unit 66 memorizes the filtered unbalance index ISF_i of each cylinder 4 immediately prior to the fault in injection system 1 being detected in block 150 (block 160), cuts off injection to completely disable injectors 14 (block 170), and closes regulating valve 12 of exhaust gas recirculating system 8 (block 180).

[0052] More specifically, regulating valve 12 of exhaust gas recirculating system 8 is closed to reduce combustion dissymmetry in cylinders 4 of engine 2 caused by anomalous combustion in turn caused by recirculation of any unburned fuel in one or more of cylinders 4, in the event one or more of injectors 14 are jammed open.

[0053] At this point, electronic central control unit 66 calculates a standby time T_0 as a function of prememorized close time values of regulating valve 12 of exhaust gas recirculating system 8, and of the convergence of the numeric filters used to filter the angular acceleration contributions AC_i of each cylinder 4 (block 190), and switches to standby for said standby time T_0, which is long enough for the transient state produced by injection cut-off and closure of regulating valve 12 to come to an end (block 200).

[0054] At the end of standby time T_0, electronic central control unit 66 calculates, for each cylinder 4, a differential unbalance index D_i equal to the difference between the unbalance index IS_i calculated immediately after the end of standby time T_0 (i.e. immediately after a fault is detected in injection system 1), and the filtered unbalance index ISF_i calculated and memorized immediately prior to a fault being detected in injection system 1 (block 210). A differential unbalance index D_i for each cylinder 4 is calculated to recover any dispersion in the angular acceleration of individual cylinders 4.

[0055] Electronic central control unit 66 then compares the differential unbalance index D_i of each cylinder 4 with a respective threshold differential index D_{THi}, which may be a constant value stored in the memory of electronic central control unit 66, or may be calculated as a function of the engine operating point (air intake, load and speed, etc.) (block 220).

[0056] If the differential unbalance index D_i of a cylinder 4 is less than or equal to the respective threshold differential index D_{THi} (NO output of block 220), electronic central control unit 66 diagnoses a fault in high- and low-pressure supply circuits 16, 18. Conversely, if the differential unbalance index D_i of a cylinder is greater than the respective threshold differential index D_{THi} (YES output of block 220), electronic central control unit 66 diagnoses a jammed-open injector.

[0057] More specifically, on detecting a fault in high- and low-pressure supply circuits 16, 18, electronic central control unit 66 limits the amount of fuel supplied to injectors 14 to limit the maximum amount of fuel that can be injected into each cylinder 4 (block 230); commands pressure regulator 48 to limit the maximum pressure the fuel can assume inside common rail 30 (block 240); and performs a further known diagnosis procedure, not described in detail, to determine whether the fault lies in high-pressure supply circuit 16 or low-pressure supply circuit 18 (block 250).

[0058] Conversely, on detecting a jammed-open injector, electronic central control unit 66 disables supply pump 22 to cut off fuel supply to injectors 14 (block 260); opens pressure regulator 48 to drain off the fuel in common rail 30 (block 270); and disables all the injectors 14 to cut off fuel injection into cylinders 4 and so turn off engine 2 (block 280).

[0059] Finally, electronic central control unit 66 displays and/or indicates acoustically the type of fault diagnosed on on-vehicle optical or acoustic indicating devices.

[0060] The advantages of the leakage diagnosis method according to the present invention are as follows:

[0061] First of all, it provides for distinguishing between fuel leakage in injection system 1 caused by a jammed-open injector, and a generic fault in the high- and low-pressure supply circuits, thus enabling drastic action to be taken on injection system 1 to stop engine 2, and hence the vehicle, when this is actually called for by the gravity of the situation (jammed-open injector), and less drastic action to be taken on injection system 1 in the case of a less serious leak, so that the vehicle can reach the nearest repair shop.

[0062] Moreover, computer simulation and road tests conducted by the Applicant show the diagnosis method according to the present invention to be reliable in any operating condition of the engine, thus overcoming the limitation of the diagnosis method referred to previously.

[0063] Clearly, changes may be made to the diagnosis method as described and illustrated herein without, however, departing from the scope of the present invention.

[0064] For example, leakage in injection system 1 may be detected otherwise than as described with reference to block 150.

[0065] More specifically, as opposed to comparing instantaneous pressure value P_{RAIL} and minimum pressure value P_{MIN}, it is possible to calculate a pressure error equal to the difference between instantaneous pressure value P_{RAIL} and a reference pressure value P_{REF} indicating the desired fuel pressure; compare the pressure error with a threshold value; and determine fuel leakage in injection system 1 when the pressure error is greater than the threshold value. Fuel leakage in injection system 1, in fact, prevents the fuel in common rail 30 from reaching the desired pressure value (P_{REF}), so that an inordinately high pressure error undoubtedly indicates leakage.

[0066] Alternatively, it is possible to compare the duty cycle of the control signal supplied to pressure regulator 48 with a threshold value; and determine leakage in injection system 1 when the duty cycle of the control signal is greater than the threshold value. Closure of pressure regulator 48, in fact, is proportional to the duty cycle of the control signal supplied to it, and the greater the closure of pressure regulator 48, the higher the fuel pressure P_{RAIL} in common rail 30 should be, so that control signal duty cycle values above the normal range, e.g. constantly over 90%, indicate the difficulty of injection system 1 in reaching the desired injection pressure (P_{REF}) and therefore the presence of a fuel leak in injection system 1.

[0067] Moreover, the injection cut-off condition commanded by electronic central control unit 66 (block 170) may be other than as described. In particular, as opposed to a total injection cut-off, in which each injector 14 is completely disabled and no fuel is injected into respective cylinder 4, a partial injection cut-off condition may be implemented, in which each injector 14 is only partly disabled, and the amount of fuel injected into respective cylinder 4 is reduced by a predetermined amount, e.g. by half.

Claims

1. A method of diagnosing leakage in a high-pressure injection system (1) of an internal combustion engine (2) comprising a number of cylinders (4); said injection system (1) comprising a number of injectors (14), each supplying high-pressure fuel to a respective cylinder (4) of said engine (2), and a fuel supply circuit (16, 18) supplying fuel to said injectors (14); and said diagnosis method being **characterized by** comprising the steps of:

   - determining, for each of said cylinders (4), a quantity (AC_i) related to the contribution of said cylinder (4) to the torque generated by said engine (2);
   - determining, for each of said cylinders (4), an unbalance index (IS_i) indicating the unbalance of the quantity (AC_i) related to the contribution of said cylinder (4) to the torque generated by said engine (2) with respect to the quantities (AC_i) related to the contributions of the other cylinders (4) to the torque generated by the engine (2);
   - reducing, upon detection of a fault in said injection system (1), the amount of fuel injected into each of said cylinders (4); and
   - distinguishing, for each of said injectors (14), between a jammed-open injector condition and a fault condition in said fuel supply circuit (16, 18), on the basis of the variation in the unbalance index (IS_i) of the respective cylinder (4) following said fuel reduction.

2. A diagnosis method as claimed in Claim 1, **characterized in that** said quantity (AC_i) related to the contribution of a cylinder (4) to the torque generated by the engine (2) is the contribution of said cylinder (4) to the angular acceleration of said engine (2).

3. A diagnosis method as claimed in Claim 1 or 2, **characterized in that** the unbalance index (IS_i) associated with each of said cylinders (4) is related to the difference between the quantity (AC_i) related to the contribution of said cylinder (4) to the torque generated by said engine (2), and a mean value of the quantities (AC_i) related to the contributions of the other cylinders (4) to the torque generated by the engine (2).

4. A diagnosis method as claimed in any one of the foregoing Claims, **characterized in that** said step of distinguishing, for each of said injectors (14), between a jammed-open injector condition and a fault condition in said fuel supply circuit (16, 18) compris-

es the steps of:

- determining a differential unbalance index (D_i) as a function of an unbalance index (IS_i) prior to detection of said fault in said injection system (1), and of an unbalance index (IS_i) following detection of said fault in said injection system (1);
- comparing said differential unbalance index (D_i) with a threshold value (D_{THi});
- determining a jammed-open injector condition when said differential unbalance index (D_i) has a first predetermined relationship with said threshold value (D_{THi}); and
- determining a fault condition in said fuel supply circuit (16, 18) when said differential unbalance index (D_i) does not have said first predetermined relationship with said threshold value (D_{THi}).

5. A diagnosis method as claimed in Claim 4, **characterized in that** said differential unbalance index (D_i) is related to the difference between said unbalance index (IS_i) prior to detection of said fault in said injection system (1), and said unbalance index (IS_i) following detection of said fault in said injection system (1).

6. A diagnosis method as claimed in Claim 4 or 5, **characterized in that** said unbalance index (IS_i) following detection of said fault in said injection system (1) is calculated at the end of a transient operating state generated by said reduction in the amount of fuel injected into said cylinders (4).

7. A diagnosis method as claimed in any one of Claims 4 to 6, **characterized in that** said unbalance index (IS_i) prior to detection of said fault in said injection system (1) is calculated immediately prior to detection of said fault in said injection system (1).

8. A diagnosis method as claimed in any one of Claims 4 to 7, **characterized in that** said step of determining a jammed-open injector comprises the step of determining whether said differential unbalance index (D_i) is greater than said threshold value (D_{THi}).

9. A diagnosis method as claimed in any one of Claims 4 to 8, **characterized in that** said step of determining a differential unbalance index (D_i) comprises the steps of:

- filtering said unbalance index (IS_i) to generate a filtered unbalance index (ISF_i); and
- determining said differential index (D_i) as a function of an unbalance index (IS_i) following detection of said fault in said injection system (1), and of a filtered unbalance index (ISF_i) prior to detection of said fault in said injection system (1).

10. A diagnosis method as claimed in any one of the foregoing Claims, **characterized in that** said step of determining an unbalance index (IS_i) for each of said cylinders (4) comprises the steps of:

- filtering the quantity (AC_i) related to the contribution of said cylinder (4) to the torque generated by said engine (2) to generate a filtered quantity (ACF_i) related to the contribution of said cylinder (4) to the torque generated by said engine (2); and
- determining said unbalance index (IS_i) as a function of said filtered quantity (ACF_i).

11. A diagnosis method as claimed in any one of the foregoing Claims, **characterized in that** said step of determining a fault in said injection system (1) comprises the steps of:

- determining the fuel pressure (P_{RAIL}) of the fuel injected by said injectors (14);
- comparing said fuel pressure (P_{RAIL}) with a threshold value (P_{MIN}) ; and
- determining said fault in said injection system (1) when said fuel pressure (P_{RAIL}) has a first predetermined relationship with said threshold value (P_{MIN}).

12. A diagnosis method as claimed in Claim 11, **characterized in that** said step of determining a fault in said injection system (1) comprises the step of determining whether said fuel pressure (P_{RAIL}) is below said threshold value (P_{MIN}).

13. A diagnosis method as claimed in any one of the foregoing Claims, **characterized in that** said fault in said injection system (1) is defined by a fuel leak in said injection system (1).

14. A diagnosis method as claimed in any one of the foregoing Claims, for an engine (2) comprising an exhaust gas recirculating system (8) having a regulating valve (12); **characterized by** also comprising the step of closing said regulating valve (12) upon detection of said fault in said injection system (1).

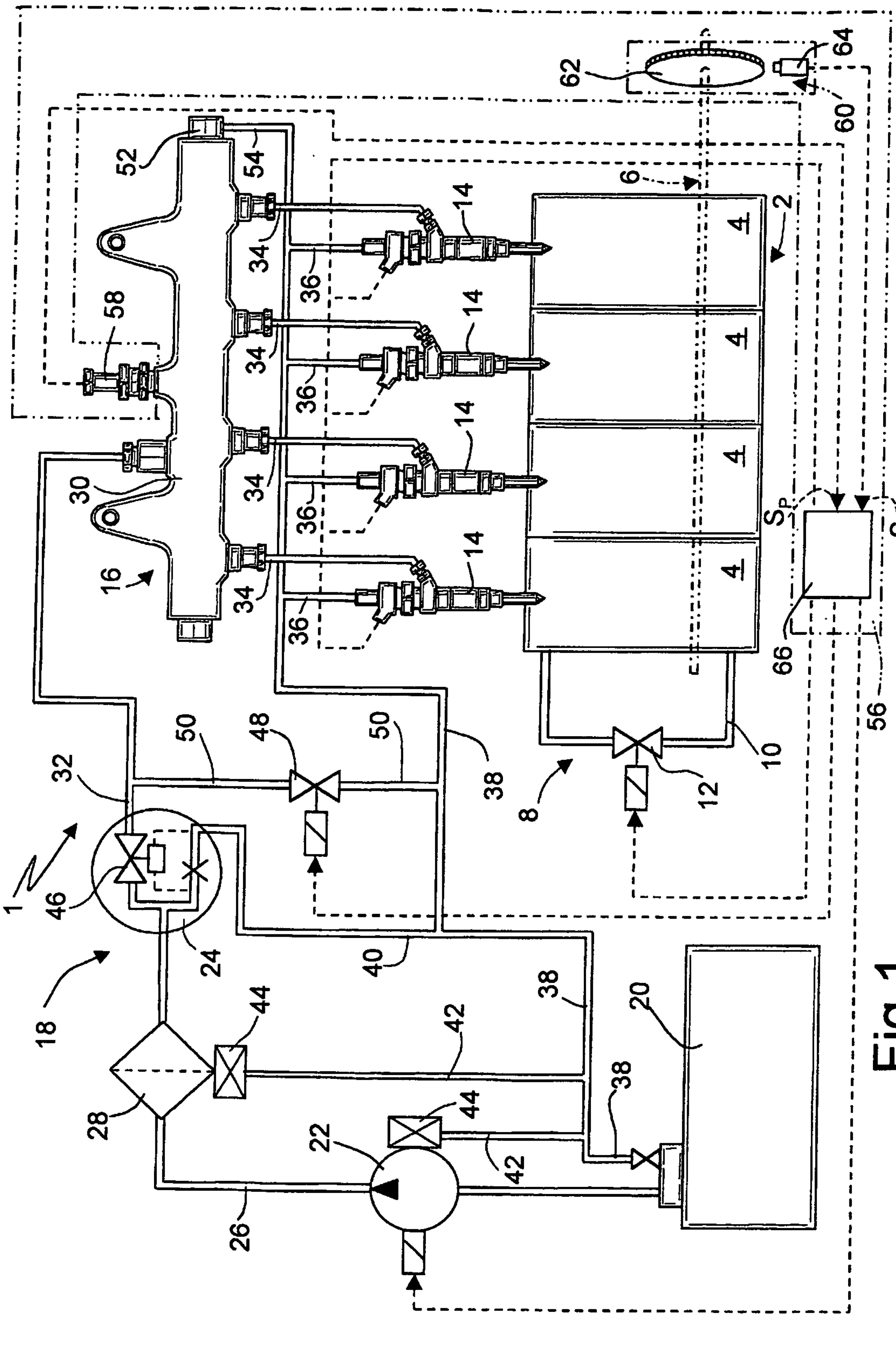
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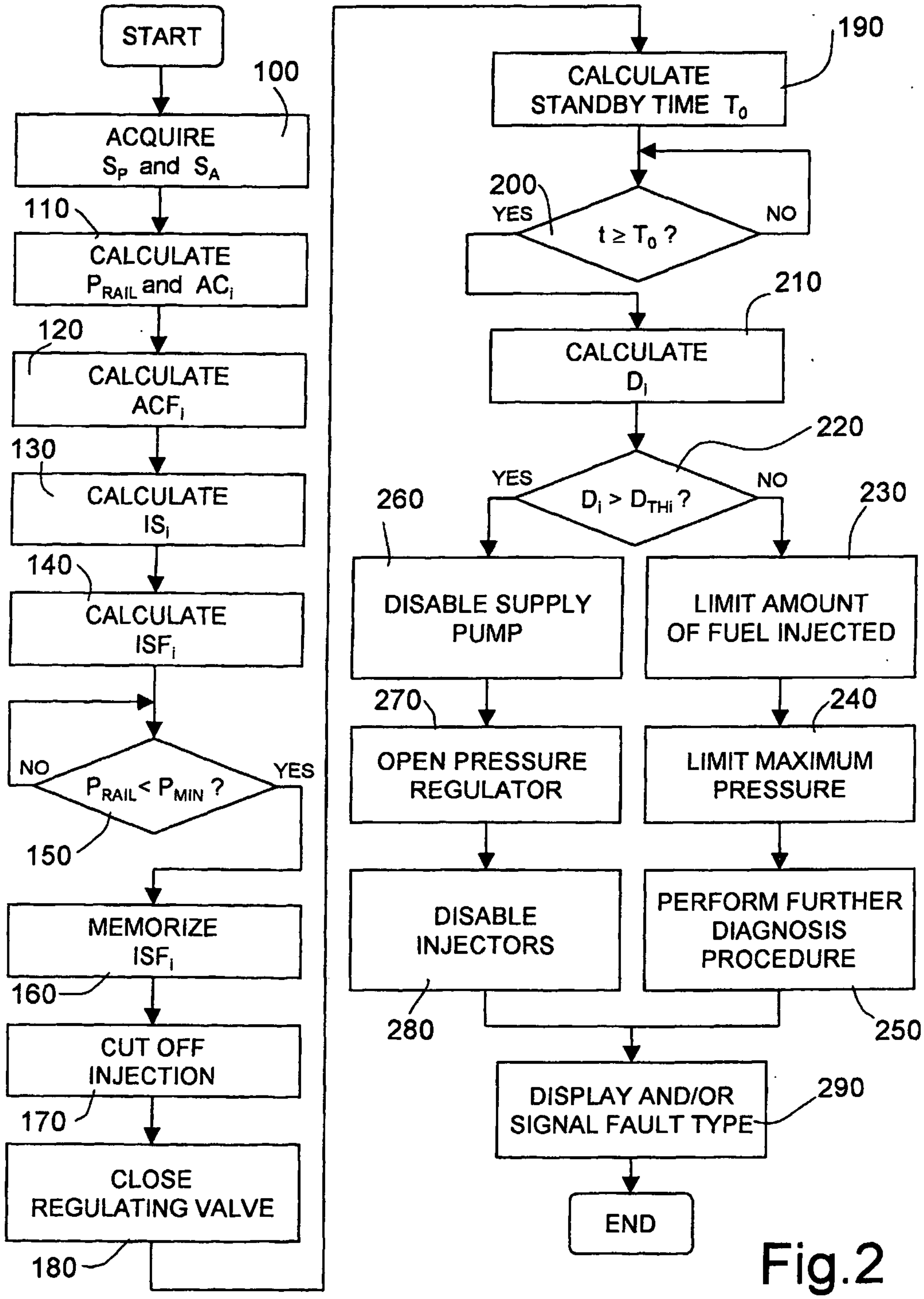
Fig.1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CALCULATE ISF_i
NO
$P_{RAIL} < P_{MIN}$?
YES
150
MEMORIZE ISF_i
160
CUT OFF INJECTION
170
CLOSE REGULATING VALVE
180
190
CALCULATE STANDBY TIME T_0
200
YES
$t \geq T_0$?
NO
210
CALCULATE D_i
220
YES
$D_i > D_{THi}$?
NO
260
230
DISABLE SUPPLY PUMP
LIMIT AMOUNT OF FUEL INJECTED
270
240
OPEN PRESSURE REGULATOR
LIMIT MAXIMUM PRESSURE
DISABLE INJECTORS
PERFORM FURTHER DIAGNOSIS PROCEDURE
280
250
DISPLAY AND/OR SIGNAL FAULT TYPE
290
END

Fig.2